Reducing death by electrocution of the white stork *Ciconia ciconia*

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Keywords
Birds; effective conservation; electrocution; electricity; Poland; power line; white stork.

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Received
21 January 2011
Accepted
13 September 2011

Editor
Andras Baldi

doi: 10.1111/j.1755-263X.2011.00203.x

Abstract

Anthropogenic changes have strongly influenced the biodiversity of Europe. In the last 50 years electric power-line networks have become a conspicuous part of the European landscape, and have strongly influenced the survival of some bird species. When they were constructed it was known, at least locally, that these lines and their support structures would cause fatalities in the white stork *Ciconia ciconia*. Annually thousands of white storks die in collision with, and through electrocution by, power lines, and these are important causes of their mortality. Using data collected in central Poland we show that technical modifications to electricity poles are an effective way to assist stork conservation and may, at least locally, reduce mortality by electrocution to zero. Because the white stork is an icon of nature conservation, we believe that public utilities and power-line companies will more readily focus on protecting this species; while indirectly aiding wider bird conservation. Furthermore, since contact with power-lines results in a break in energy transmission, these modifications also positively benefit both energy consumers and power companies.

Introduction

For the past 50 years, electric power lines have been a conspicuous part of the landscape in Europe. When constructed it was anticipated that these lines and their support structures, as with other human structures such as wind turbines and buildings, would result in bird fatalities (e.g., Bevanger 1998; Janss 2000; Infante & Peris 2003; Martin & Shaw 2010). However, the economic argument that it is cheaper and easier to build and maintain overhead, rather than underground, power lines usually prevails. Birds may be affected not only directly by contact with power lines, but also by their electromagnetic fields (Balmori 2005). However, electrocution by, and collisions with, power lines are a major anthropogenic mortality factor in birds and kill several thousand birds each year (Bevanger 1994; Janss 2000; Martin & Shaw 2010; Tintó *et al.* 2010). Moreover, collisions between birds and power lines have a serious commercial consequence; mainly connected with the temporary disruption of energy transport (Bevanger 1998; Infante & Peris 2003).

Obviously power lines do not affect all bird species in the same way, but especially affect larger bird species and those that use power-line structures for nesting or roosting (Bevanger 1994; Janss 2000; Haas & Nipkow 2006). The white stork *Ciconia ciconia*, a charismatic species and icon of nature conservation in Europe and worldwide (Schulz 1998; Tryjanowski *et al.* 2006), is among the species most susceptible to electrocution and collision (Garrido & Fernandez-Cruz 2003; Schaub & Pradel 2004; Martin & Shaw 2010). The eastern population of the white stork, centered on Poland, is entirely migratory, breeding in Europe and overwintering in sub-Saharan Africa. The bird is large (2 m wingspan), long-lived (c. 30 years), and usually both site- and mate-faithful. White storks nest in close association with human settlements, are generally welcomed and tolerated, and even viewed as "part of the family."

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Consequently the health and survival of storks is of great local interest and their death through electrocution can affect human emotions. This was the catalyst to address the described problem because a lot of local people, mainly farmers, were taking dead and injured storks to zoos, avian rehabilitation centers, and local veterinary clinics (Tryjanowski *et al.* 2006). Motivating conservation focused on the white stork is therefore relatively easy. For biodiversity the bonus is that the species appears to be a good indicator of both environmental conditions and farmland diversity, as well as of other large birds killed by electrocution in a similar way (Dillingham & Fletcher 2008). Therefore, the suggested solutions have wider benefits than just those to white storks (Tryjanowski *et al.* 2006; Olsson & Rogers 2009).

In Europe, over a 16-year period, it was estimated that approximately 25% of juvenile and 6% of adult white storks died annually from power-line collisions and electrocution (Schaub & Pradel 2004). Therefore, power-line mortality is a conservation problem for this and many other bird species, mainly for large birds such as raptors and owls (Bevanger 1998; Infante & Peris 2003).

A simple modification to reduce avian mortality by preventing electrocution on power lines, mainly by installation of electrocution-safe poles or other power-insulating devices, has been suggested as a good practical solution (Bevanger 1998; Haas & Nipkow 2006). These recommendations, summarized in the "Budapest Declaration on bird protection and power lines" in April 2011 (http://www.mme.hu/binary_uploads/6_termeszetvedelem/elektromos_halozat_es_madarvedelem/budapest_declaration.pdf) benefit both birds and humans (both companies and consumers), since they also reduce the number of breaks in energy transmission (Bevanger 1998; Haas & Nipkow 2006).

In this article we show how technical modifications to electricity poles may reduce local mortality from electrocution to zero, which is an extremely good example of successful protection of a species that may be used to promote conservation elsewhere.

Materials and methods

Data were collected in 2008–2010 to the east of Warsaw in central Poland. The study site covered 3,700 km^2, and the proportions of different habitats were: arable fields 36%, meadows and pastures 32%, with the remainder forests, lakes, and human settlements (for details see Guziak & Jakubiec 2006). The mean density of breeding white stork pairs was 20 per 100 km^2, producing an annual average of 2.8 fledglings each.

Data on deaths by electrocution were collected by a joint initiative of local naturalists visiting poles and by workers of power-line companies during inspections. Electrocutions took place from late July to early August just before migration to Africa when birds roost on electricity structures. The number of dead birds was recorded and age (juvenile or adult, determined by leg and bill color and plumage development) was noted.

Because the number of dead storks was so high in 2008 it was decided to prepare an action plan and, since 2009, to make technical modifications to electricity poles, including providing isolators and disconnectors to particular poles (all triangle poles for medium voltage transfer 110 kV—Figure 1). For 43 electricity poles, modifications were made prior to the 2009 season and the number of deaths at each recorded in 2008 (prior to modification) and 2009 (after modification). A further 27 electricity poles were modified before the 2010 season and deaths were recorded before (2009) and after (2010) modification. Deaths were monitored at 25 unmodified electricity poles in 2008 and repeated in 2009 and 2010.

Means and standard errors of deaths were calculated for each of the above groups in each recorded year. Before–After comparisons were made of deaths at the 2009 modified electricity poles, and separately for the 2010 modified electricity poles. Because of the discrete nature of the data, randomization (resampling) tests with 1,000 permutations (year randomized within pole) were carried out against null hypotheses of the change experienced in the unmodified poles (see Table 1), that is, a mean *increase* in deaths per pole of 0.32 from 2008 to 2009 and a mean *increase* of 0.64 from 2009 to 2010. As an alternative to two way ANOVA (25 poles × 3 years), differences between years in deaths on the unmodified electricity poles were tested using a randomization test with 1,000 permutations (years randomized within poles).

The importance of this conservation activity was investigated by a simple model of additional human-caused mortality on potential biological removal (PBR, after: Dillingham & Fletcher 2008). PBR is the maximum number of animals, not including natural mortalities, which may be removed while allowing that stock to reach or maintain its optimum sustainable population. The parameters used in this model were: age at first breeding = 4 years; yearly adult survival probability = 0.82; f value used to implement alternative management strategies = 0.5 (suggested by Dillingham & Fletcher 2008 for "least concern species" according to IUCN criteria). These values generate a value of the maximum recruitment rate $R_{max} = 0.155$. All values were based on the eastern stork population using results from Schaub & Pradel (2004), Sæther *et al.* (2005), and Tryjanowski *et al.* (2006). The size of the local population was taken as 740 breeding pairs, which in practice equates to 1,508 adults, and at the

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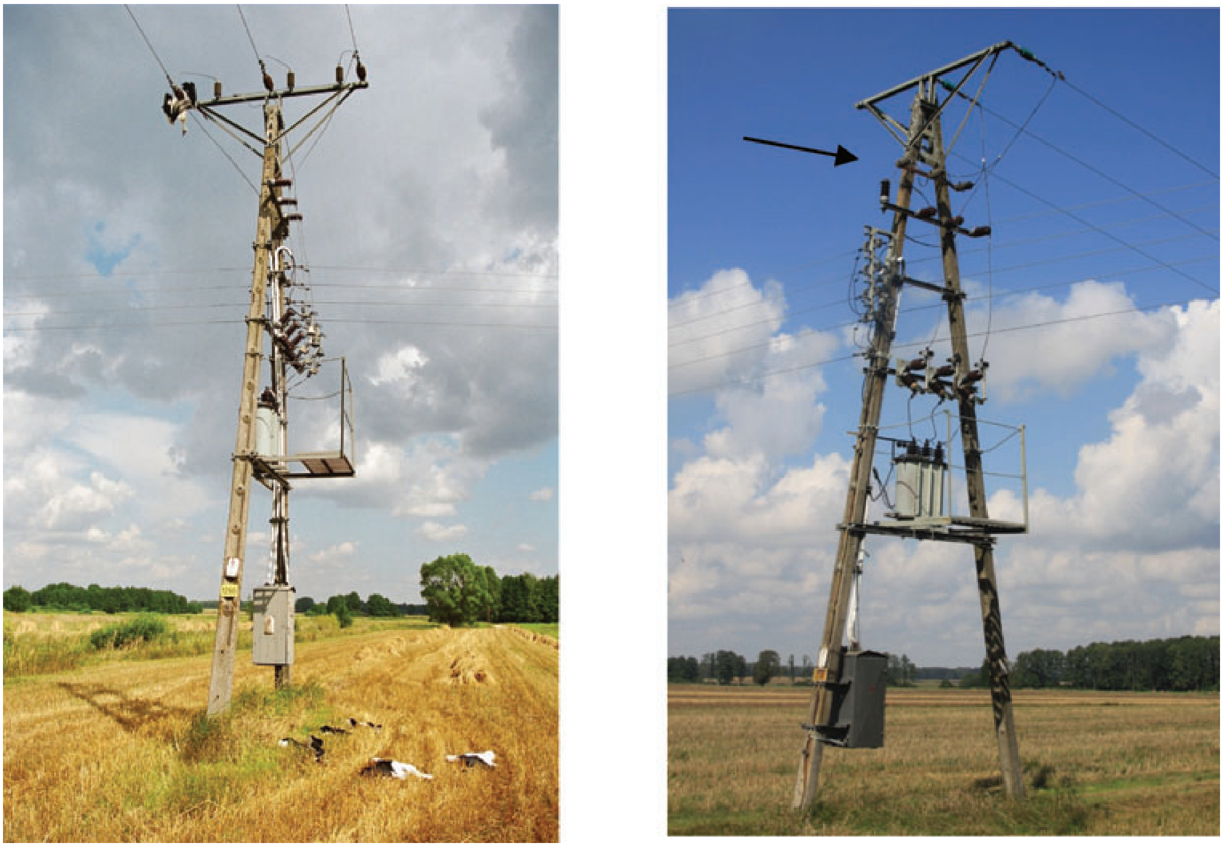

Figure 1 An electricity pole before (left) and after (right) technical modifications (indicated by an arrow) to reduce electrocution of birds. Note the five electrocuted white storks on the ground, and a further one on top of the pole, in the first photograph.

end of the breeding season the total local population size was ca. 3,200 individuals (i.e., including fledged chicks).

Results

Of 290 recorded deaths, only 8 were of adult birds. This is in sharp contrast to the proportions of birds counted in the study area (1,508 adults, 2,107 juveniles). A chi-square test confirmed that juvenile deaths were proportionately significantly higher than expected by chance ($\chi^2_1 = 181$, $P < 0.001$). Detected electrocutions exceeded 5% of the juvenile cohort in the study area.

Mean numbers of deaths by year and group are summarized in Table 1. For both sets of modified electricity poles, no deaths were recorded following modification, although deaths were still recorded at unmodified poles. As expected, the reduction in the number of deaths was highly significant following modification in 2009 (randomization test, $P < 0.001$) and in 2010 (randomization test, $P < 0.001$). Deaths on the unmodified posts varied significantly between years (randomization test, $P = 0.012$) with more deaths apparent in 2010 (Table 1).

Estimation of PBR suggests a loss of 58 to 124 individuals per year is possible while sustaining normal population functioning. Conservative estimation of loss, on the assumption that all dead storks were recorded and electrocution was the only source of mortality with power lines, is within the above range (i.e., 97 birds per year), which means that at least in some years electrocutions are a serious source of mortality with a directional effect on realized population growth rate.

Table 1 The mean and standard error (SE) of the number of white stork *Ciconia ciconia* deaths per electricity pole for the groups and years mentioned in the text

Type of electricity pole	year	mean	SE
2009 modifications ($n = 43$)	2008 (before)	2.28	0.22
	2009 (after)	0.00	0.00
2010 modifications ($n = 27$)	2009 (before)	1.70	0.16
	2010 (after)	0.00	0.00
Unmodified ($n = 25$)	2008	1.52	0.12
	2009	1.84	0.16
	2010	2.48	0.26

Discussion

We have shown that electrocution is a serious cause of mortality in white storks, which confirmed results from other locations (Jakubiec 1991; Garrido & Fernandez-Cruz 2003; Schaub & Pradel 2004). This number is still probably an underestimate because it excludes deaths by collision and many of those killed are not found and are eaten by scavengers (Bevanger 1994, 1998; Lehman *et al.* 2007). However, death in this species may be easier to detect than in other affected species because of its size, iconic status, and high visibility. Electrocution is especially damaging to the juvenile cohort rather than adult birds, with the number of juvenile deaths proportionately much higher than expected by chance. Similarly, other studies also show that electrocution is more common in juvenile birds and may seriously affect the local population structure (Schaub & Pradel 2004). One possible reason for high mortality is that nesting by white storks in Poland on electricity posts is increasing (Tryjanowski *et al.* 2009), which may increase risks of electrocution, especially of young storks during their maiden flights (Jakubiec 1991; Garrido & Fernandez-Cruz 2003; Schaub & Pradel 2004). However, in our study none of the poles with electrocution fatalities were occupied by a white stork nest.

Our results indicate that in our study area electrocution, as a mortality factor in white stork (and possibly also in other bird species—see Janss & Ferrer 1999), may be reduced to zero and thus its elimination is very effective in supporting the conservation effort for this particular species, and presumably many others. A conservative estimate of the number of juvenile birds saved from electrocution in 2010 is 2.48 birds per electricity pole (i.e., the 2010 mean for the unmodified poles); which for 70 modified poles equates to 173 birds.

To reduce the probability of electrocution different solutions have been proposed, from changing the line route, to the modification of power lines (especially during reconstruction), for example, by the use of suspended insulators (for new recommendations see: http://www.mme.hu/binary_uploads/6_termeszetvedelem/elektromos_halozat_es_madarvedelem/budapest_declaration.pdf). In particular, overhead electric cables may be buried which is an effective way to not only reduce bird, including white stork, mortality, but is also important from a landscape perspective. In this article we clearly show that conservationists, ornithologists, energy companies, and local politicians can, and should, collaborate to effectively reduce the threat of bird electrocution. It is difficult to say how important our conservation activity is in a more general context because of a lack of quantitative data from other regions within the geographical range of the white stork. However, similar benefits were reported (but not statistically analyzed) in Germany and Spain (Garrido & Fernandez-Cruz 2003; Haas & Nipkow 2006). Moreover, the suggested modification to electricity poles is very cheap. Considering only economic costs (equipment, labor, and losses resulting from power outages associated with the modernization of the pole), the modification costs are equal to ca. 4,700 Polish Złoty (= ca. 1,200 Euro) per pole. Expenditure is recovered after 1 year of device operation (by reduced failure of energy transport arising from birds collisions).

In conclusion, our results indicate that electrocution of white storks can (almost) be eliminated by a well-tested simple modification to electricity poles. The allocation of resources by public utilities and power-line companies to bird conservation, especially to species as charismatic as the white stork, is therefore justified.

Acknowledgments

This work was a part of the project "Active protection of the White Stork in the Masovia region" and was made possible through the financial support of the regional utility Polska Grupa Energetyczna Zakład Energetyczny Warszawa Teren, the Norwegian Financial Mechanism Foundation Ekofundusz, and the private company Hurtownia Elektryczna Asaj. Ryszard Rys provided expert help in installation of the power-insulating devices. We thank the editors and referees of Conservation Letters for comments on earlier versions of this article.

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